TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 788

DRAG DETERMINATIONS OF THE FORWARD COMPONENT OF A TRICYCLE LANDING GEAR

By Hubert N. Harmon
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SUMMARY

Wind-tunnel tests were performed to determine the drag of the front-wheel arrangements of several types of tricycle landing gear. One wheel was tested in arrangements to simulate both nonretracted and partly retracted types. The landing gears were tested in conjunction with a fuselage, and the effects of wheel extension and longitudinal location were determined.

The drag changed very little with either longitudinal location or wheel extension for the landing gear with the lowest drag: a completely faired landing gear of the wheel-spat, single-strut type. The drag of the trouser-type landing gear increased considerably, however, with an increase in the wheel extension. The wheel of the unfaired retractable landing gear was at least one-half retracted into the fuselage before the drag became less than that of the best nonretracted landing gear. The drag per unit frontal area of the landing gears of the present tests was about the same as that found for similar landing gears in earlier tests.

INTRODUCTION

Several years ago tests of a large number of conventional two-wheel landing gears alone and also in combination with fuselage, wings, and nacelle were made by the NACA. (See references 1, 2, and 3.) These tests contributed a considerable amount of basic information about the drag of landing gears. The drag of the fixed and the partly retracted forward component of the tricycle landing gear could not be predicted with certainty from the previous tests because these tests did not include landing gears that were located at the forward end of the fuselage.

The tests herein reported were made to determine the drag of nose-wheel landing-gear arrangements and possible variations peculiar to tricycle landing gears. The landing gears tested were restricted to a few cantilever types found to be good in the earlier tests. Most of them were tested in four longitudinal positions.

APPARATUS

The tests were made in the NACA 20-foot wind tunnel. (See reference 4.) The return passages of the tunnel have been slightly altered and a new six-element balance has been installed since reference 4 was written.

The fuselage to which the landing gears were fitted is shown supported on the balance in figure 1. The forward half of the fuselage is approximately elliptical in cross section; the nose and the windshield approximate the shape of the nose and the windshield on a modern transport fuselage.

The landing gears tested may be classed as nonretracted and partly retracted types. The wheel used for all tests is a $\frac{1}{2.72}$ -scale model of a nominal 47-inch smooth contour wheel. The unfaired wheel and fork are shown in figure 2. Figure 3 shows the landing gear designated strut-faired landing gear. A streamline fairing of Navy 1 strut section is slipped over the round strut. Figures 4 and 5 represent complete fairings designated I and II, which are the wheel-spat, single-strut type and the trouser type, respectively.

Complete fairing II is obtained by slipping the large streamline cylindrical fairing down over the strut and the wheel to the maximum section of the wheel fairing, which it fits snugly. The partly retracted landing gears tested included an unfaired landing gear alone and retracted into the streamline fairing, both with and without the fairing cap. The fairing is shown in figure 6.

METHODS

All the landing gears were tested in conjunction with the fuselage, which was set at zero pitch. Figure 7 is a composite sketch showing part of the outline of the wheel in each position tested. The longitudinal locations are called positions A, B, C, and D and the radial location along any of these lines is given as a certain extension in wheel diameters measured from the outermost wheel surface. Figures 8 to 32 show the various arrangements, the modifications, and the drag results.

Drag and dynamic pressure were measured for every arrangement.

PRECISION

Based on the check of zero readings and on repeat tests, the drag is believed to be accurate to within ±0.5 pound. The relative precision of the tests made close together in a series, in which the fillet was the only change, is with few exceptions believed to be within ±0.2 pound.

RESULTS AND DISCUSSION

All drag values presented in this report were taken from faired curves of drag plotted against dynamic pressure. The most useful of the results given in figures 8 to 32 are summarized in tables I and II. Plots of drag against wheel extension for the various types of gear are shown in figure 33. Figures 34 and 35 show the variation of drag with the longitudinal location. These three figures present the chief trends and the local deviations from them.

The nonretracted landing gears in order of decreasing drag are: unfaired landing gear, strut-faired landing gear, completely faired landing gear II, and completely faired landing gear I. One exception to this order is found in position C, where the completely faired landing gear II at less than 1.16 diameter extension is lower in drag than the completely faired landing gear I at the same extension.

The partly retracted landing gears in order of decreasing drag are: the landing gear in streamline fairing with cap off, the unfaired landing gear alone, and the landing gear in streamline fairing with the cap on.

The drag of the unfaired landing gear in the streamline fairing with the cap on is much lower than that of any of the nonretracted landing gears extended more than 1.25 wheel diameters, but the unfaired landing gear alone must be retracted almost 0.5 diameter before its drag is reduced to that of the best nonretracted landing gear.

There is a general trend of increased drag with an increased extension, but the drag of the completely faired landing gear I remains substantially constant with an increase in the extension. The unfaired landing gear and the completely faired landing gear II show the greatest increases with extension.

The drag of each landing gear either does not change or initially increases as the landing gear is moved to a more rearward position. Of the landing gears tested in the most rearward position D, only ~~the~~ unfaired landing gear had a lower drag than the same landing gear in the next forward position C. Of the nonretracted landing gears, the unfaired landing gear and the strut-faired landing gear showed the greatest change in drag with longitudinal position. The partly retracted landing gears showed practically no change with longitudinal position.

Fillet changes on the completely faired landing gear I had only a small effect. Fillet changes on the completely faired landing gear II caused considerable change in drag, but the variation with fillet size was not regular.

The drag per unit frontal area of the completely faired landing gears I and II was about the same as that found for the similar landing gears B and A, respectively, of reference 2.

CONCLUSIONS

The drag changed very little with either longitudinal location or wheel extension for the landing gear with the lowest drag: a completely faired landing gear of the wheel-spat, single-strut type. The drag of the trouser-type landing gear increased considerably, however, with an increase in the wheel extension. The wheel of the unfaired retractable landing gear was at least one-half retracted into the fuselage before the drag became less than that of the best nonretracted landing gear. The drag per unit frontal area of the landing gears of the present tests was about the same as that found for similar landing gears in earlier tests.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., October 10, 1940.

REFERENCES

1. Herrnstein, William H., Jr., and Biermann, David: The Drag of Airplane Wheels, Wheel Fairings, and Landing Gears - I. Rep. No. 485, NACA, 1934.

2. Biermann, David, and Herrnstein, William H., Jr.: The Drag of Airplane Wheels, Wheel Fairings, and Landing Gears. II - Nonretractable and Partly Retractable Landing Gears. Rep. No. 518, NACA, 1935.

3. Herrnstein, William H., Jr., and Biermann, David: The Drag of Airplane Wheels, Wheel Fairings, and Landing Gears - III. Rep. No. 522, NACA, 1935.

4. Weick, Fred E., and Wood, Donald H.: The Twenty-Foot Propeller Research Tunnel of the National Advisory Committee for Aeronautics. Rep. No. 300, NACA, 1928.

TABLE I

Drag at 100 mph of Nonretracted Landing Gear and Wheel Arrangements

[Drag values given are for optimum fillets. For fillet dimensions used and for values obtained with fillet arrangements with higher drag, see figs. 8 to 28, inclusive.]

Fairing and reference	Wheel extension (diam.)	Drag, lb			
		Position A	Position B	Position C	Position D
Unfaired (fig. 2)	2.00	7.9	9.5	13.5	13.0
	1.50	5.9	7.1	10.7	9.8
	1.13	3.1	-	-	-
	1.06	-	5.7	9.9	8.0
Strut fairing (fig. 3)	2.02	4.4	5.4	-	-
	2.01	-	-	8.3	-
	1.52	-	5.2	-	-
	1.50	3.9	-	7.5	-
Complete fairing I, wheel-spat and strut type (fig. 4)	2.00	1.9	2.0	2.5	4.0
	1.50	1.5	2.4	2.5	3.8
	1.50	-	[a]3.4	-	-
	1.25	1.7	-	-	-
	1.16	-	2.0	-	-
	1.11	-	-	2.6	-
Complete fairing II, trouser-type (fig. 5)	2.00	-	5.2	5.2	7.5
	1.50	-	4.6	4.8	4.9
	1.06	-	2.1	-	-
	1.02	-	-	.4	-

[a]Wheel clearance increased by trimming off 1 inch of fairing.

TABLE II

Drag at 100 mph of Partly Retracted Landing-Gear and Wheel Arrangements

(Drag values given are for optimum fillets. For fillet dimensions, see figs. 29 to 32, inclusive)

Fairing and reference	Wheel extension (diam.)	Drag, lb			
		Position B	Position C	Position D	Partly retracted into tip of nose
Unfaired gear (fig. 2)	0.75	4.0	4.8	-	-
	.50	1.0	1.6	1.7	0.6
	.25	.5	.6	1.2	-
Streamline fairing, cap off (fig. 6)	0.75	6.9	6.8	-	-
	.50	5.2	4.9	-	-
Streamline fairing, cap on (fig. 6)	0.75	0.5	0.8	-	-
	.50	-.1	.0	-	-

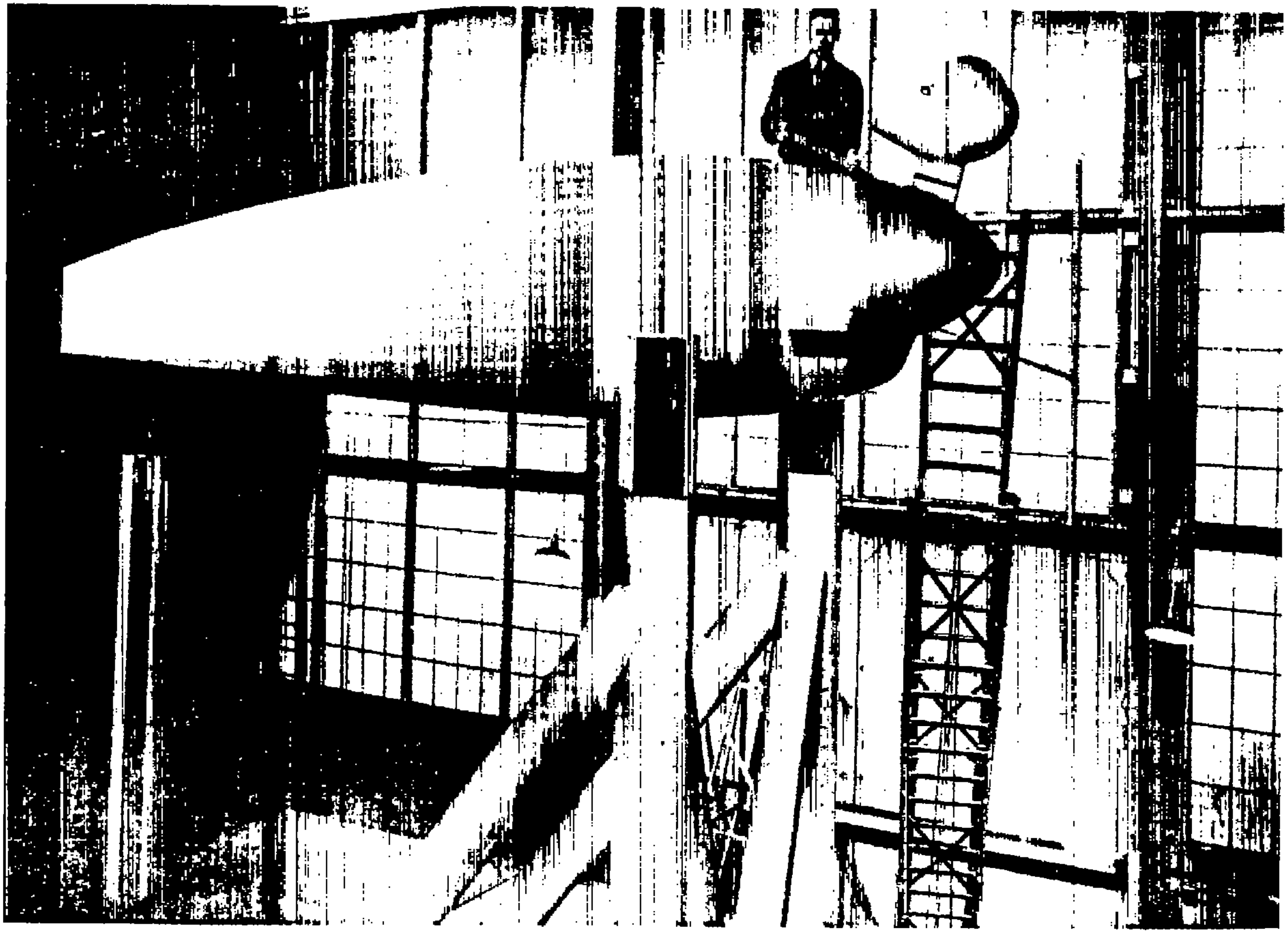


Figure 1. - Fuselage and landing gear with complete fairing I mounted in the 20-foot wind tunnel. Wheel extended 1.5 diameters in position B.

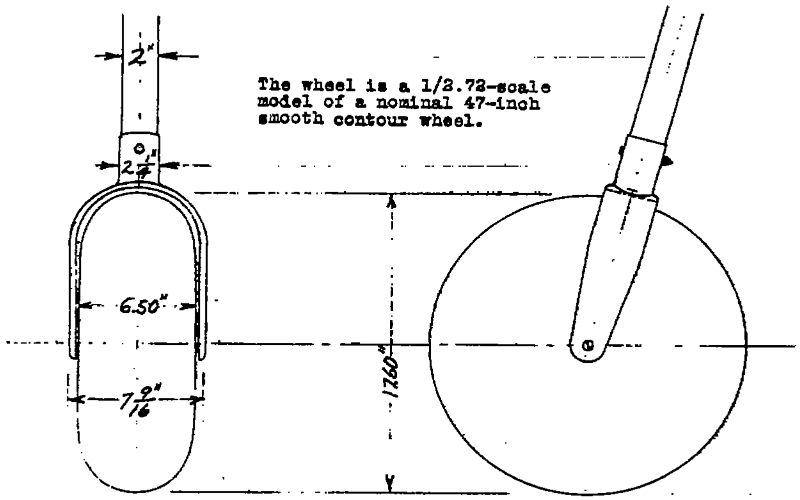


Figure 2.- Unfaired landing gear.

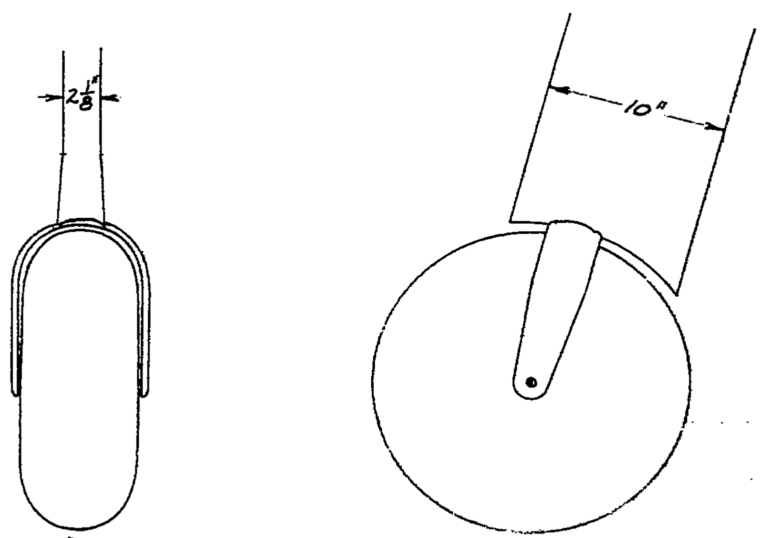
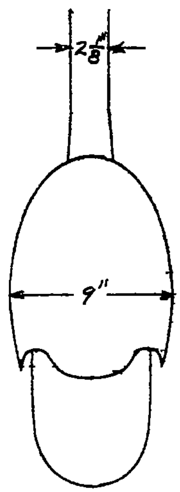


Figure 3.- Landing gear with strut fairing.



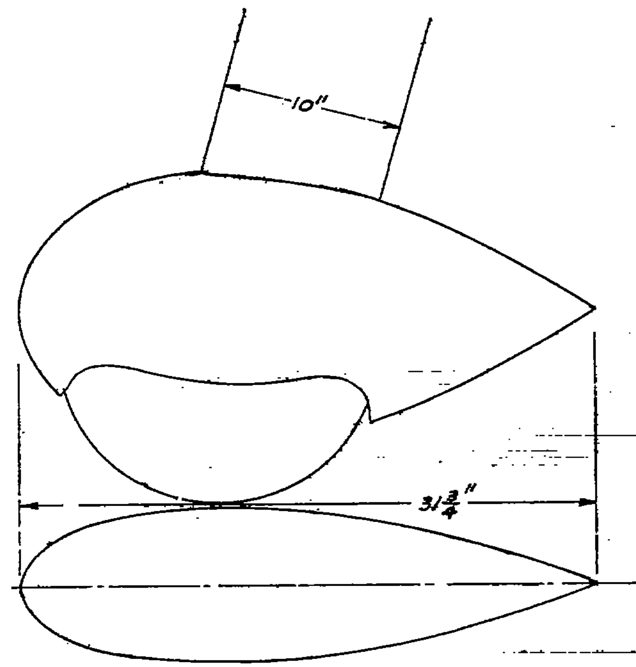


Figure 4.- Landing gear with complete fairing I.

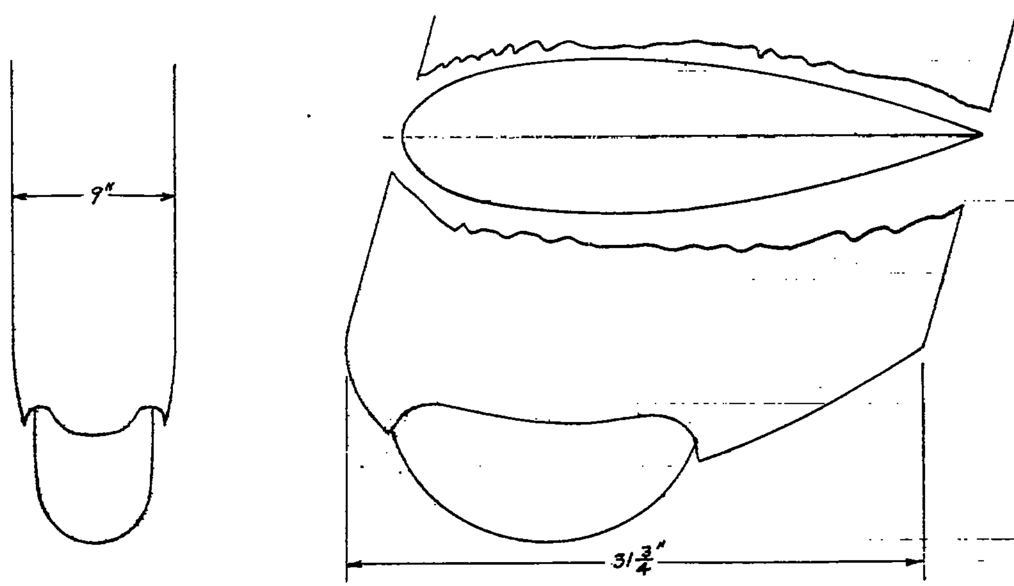


Figure 5.- Landing gear with complete fairing II.

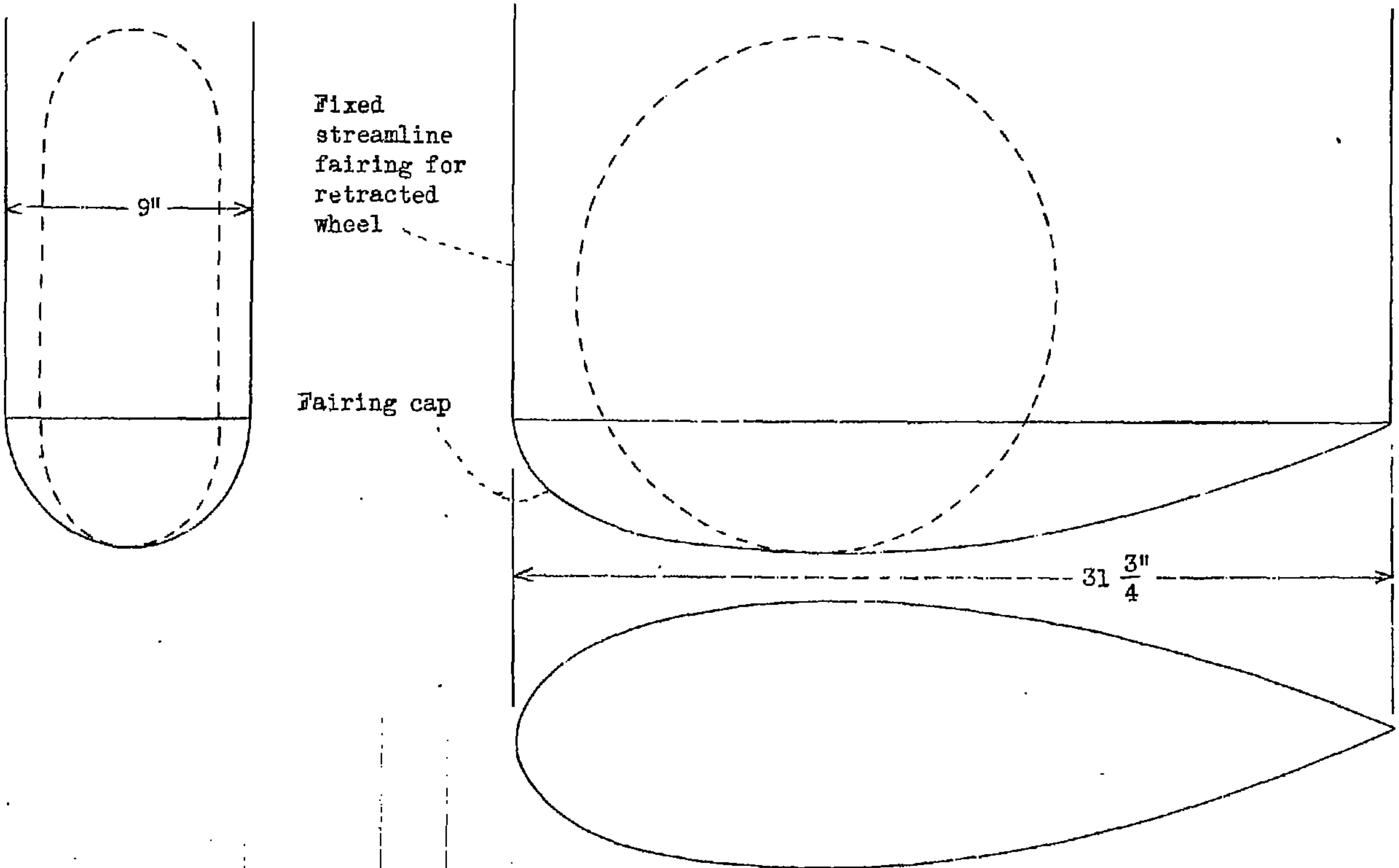
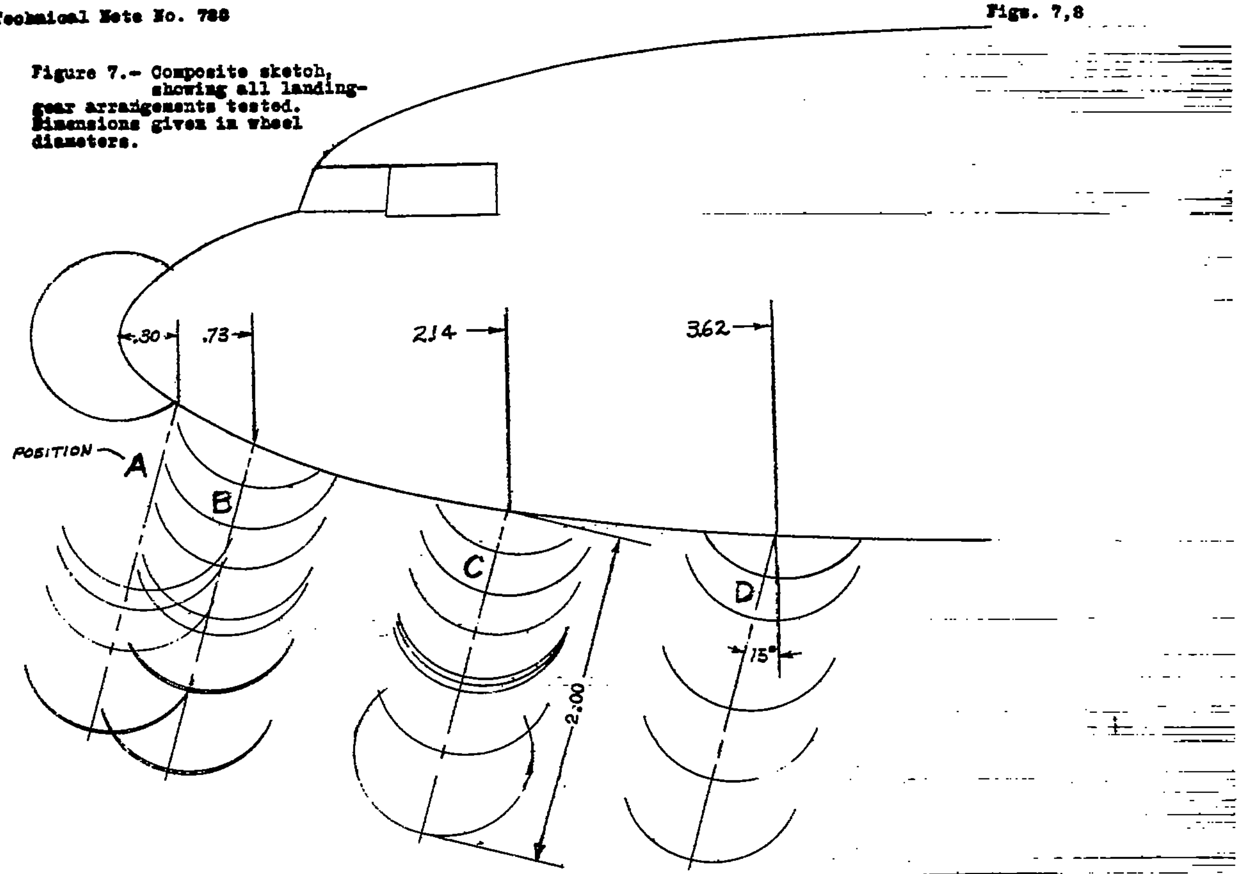
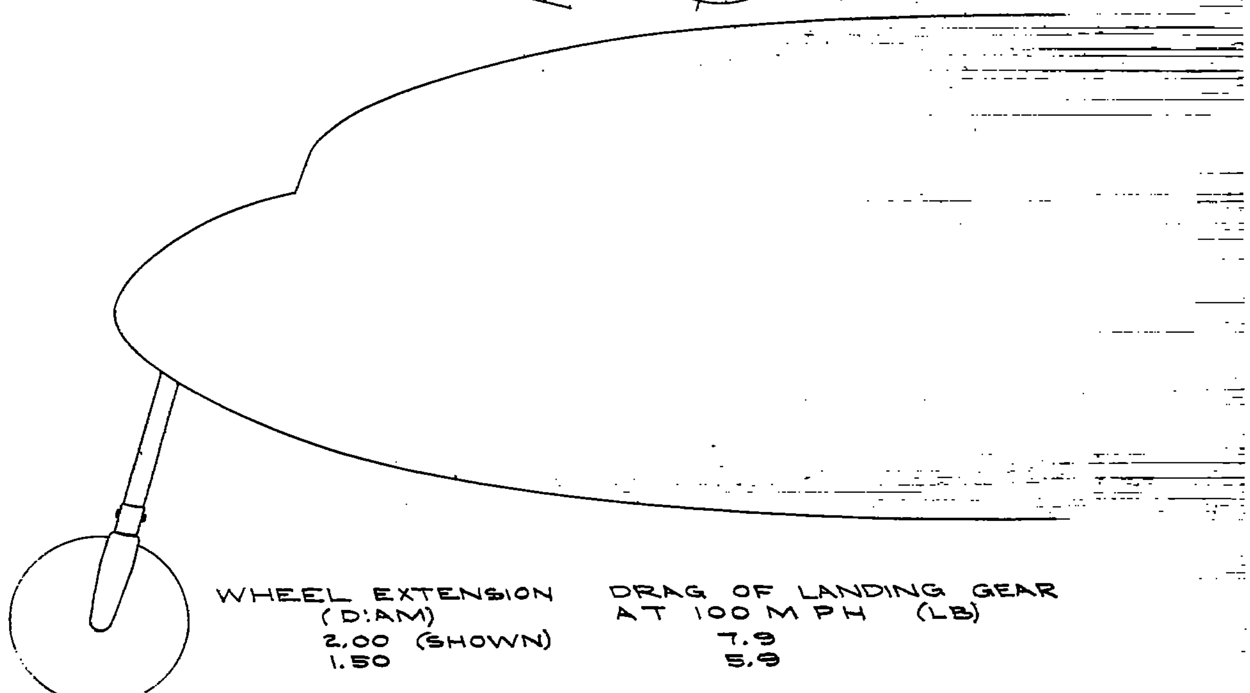


Figure 6.- Fairing for partly retracted landing gear.

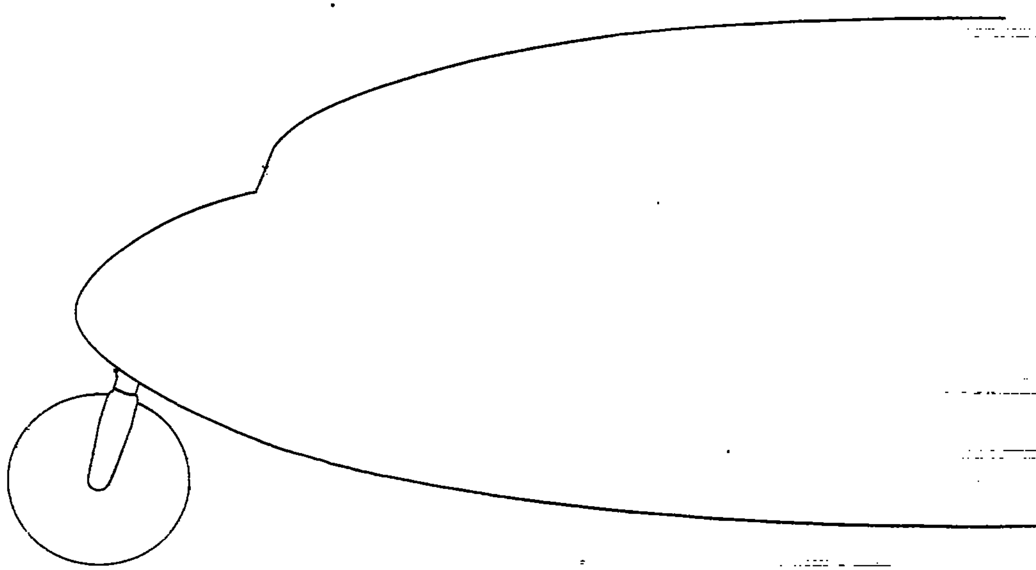
Figure 7.- Composite sketch, showing all landing-gear arrangements tested. Dimensions given in wheel diameters.





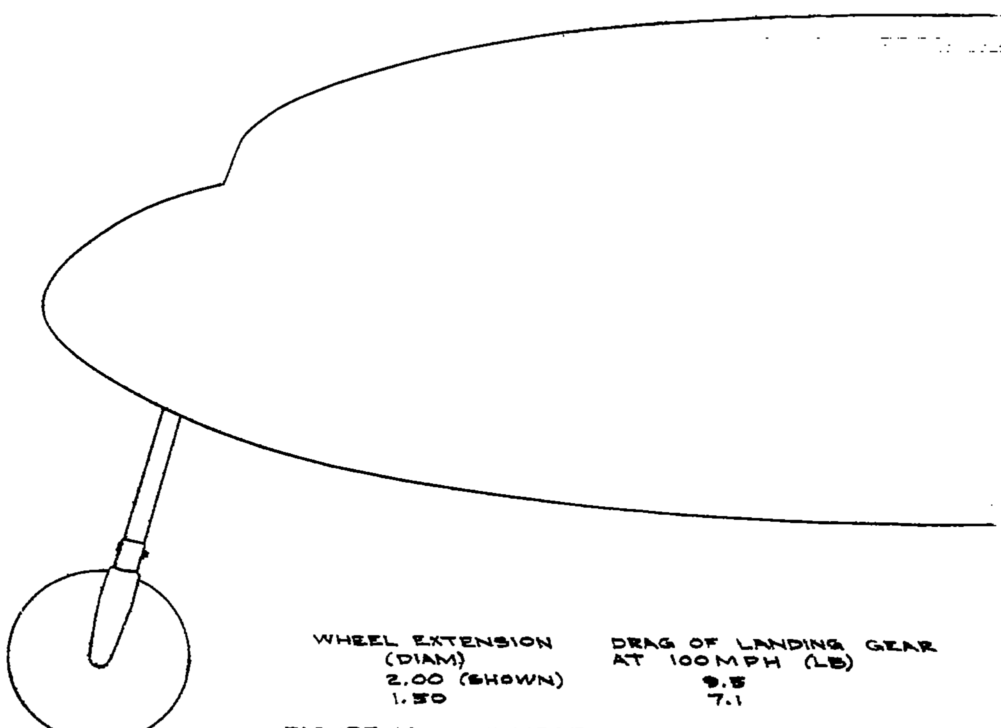
WHEEL EXTENSION (DIAM)	DRAG OF LANDING GEAR AT 100 MPH (LB)
2.00 (SHOWN)	7.9
1.50	5.9

FIGURE 8.- UNFAIRED LANDING GEAR. POSITION A



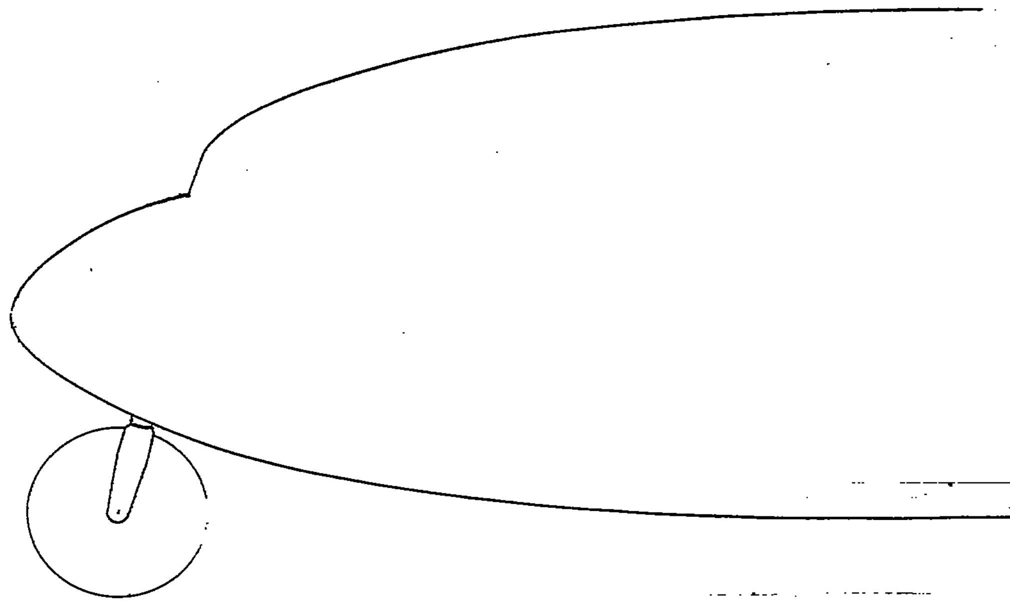
WHEEL EXTENSION (DIAM)	DRAG OF LANDING GEAR AT 100 M.P.H. (LB)
1.13	3.1

FIGURE 9.- UNFAIRED LANDING GEAR. POSITION A.



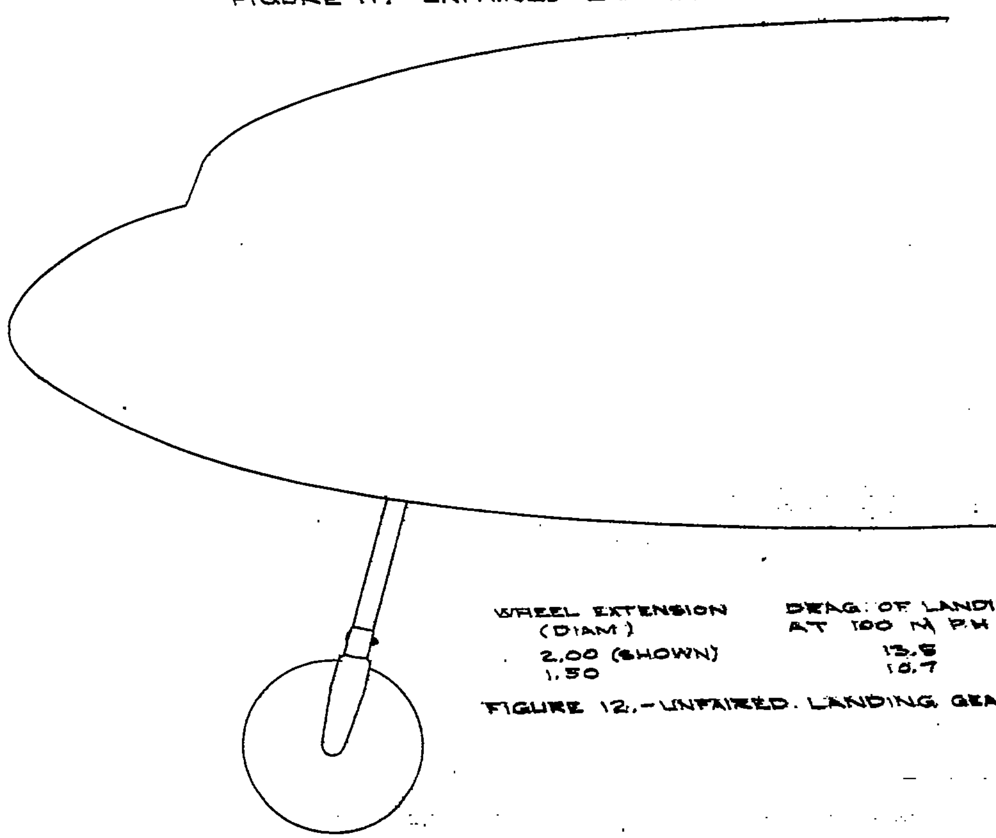
WHEEL EXTENSION (DIAM)	DRAG OF LANDING GEAR AT 100 MPH (LB)
2.00 (SHOWN)	9.5
1.50	7.1

FIGURE 10. - UNFAIRED LANDING GEAR. POSITION B.



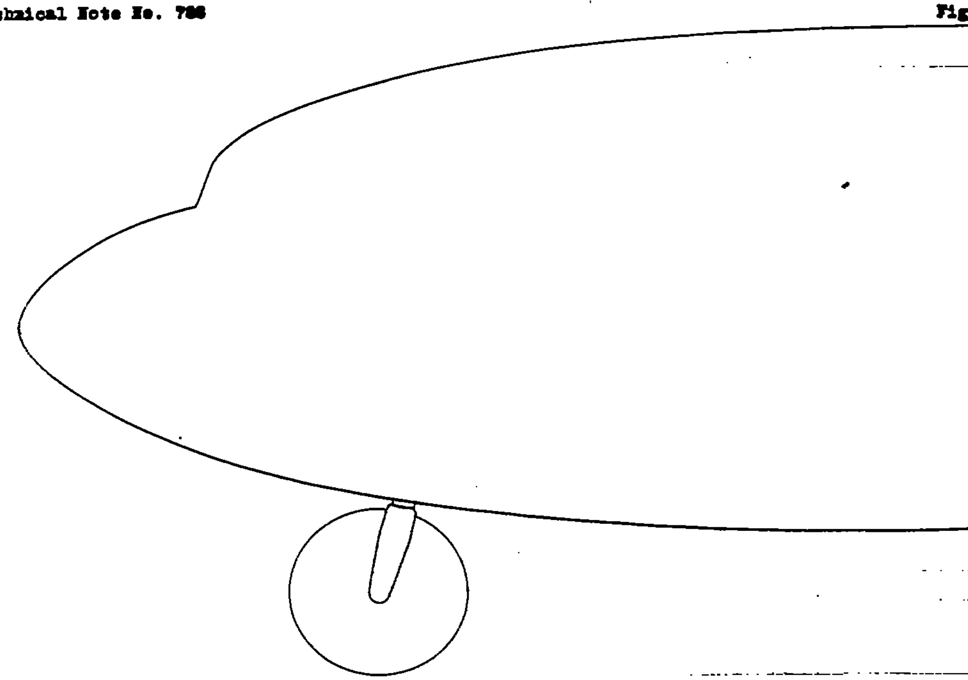
WHEEL EXTENSION (DIAM)	DRAG OF LANDING GEAR AT 100 MPH (LB)
1.06	5.7

FIGURE 11.- UNFAIRED LANDING GEAR, POSITION B.



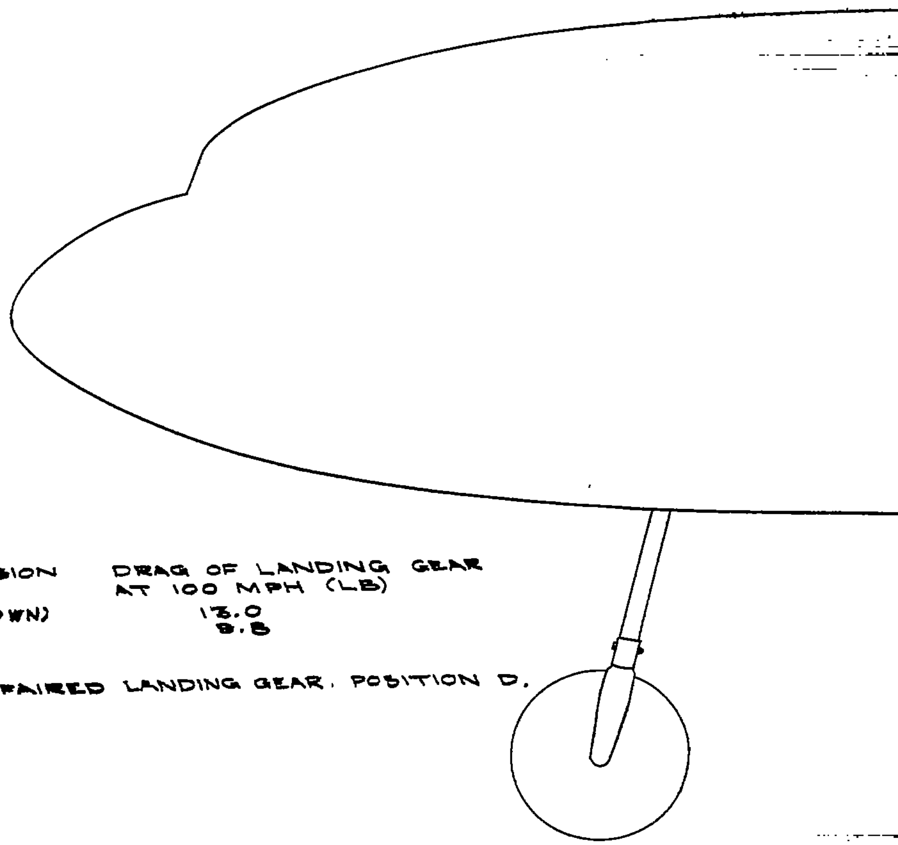
WHEEL EXTENSION (DIAM)	DRAG OF LANDING GEAR AT 100 M P H (LB)
2.00 (SHOWN)	13.8
1.50	10.7

FIGURE 12.- UNFAIRED LANDING GEAR, POSITION C



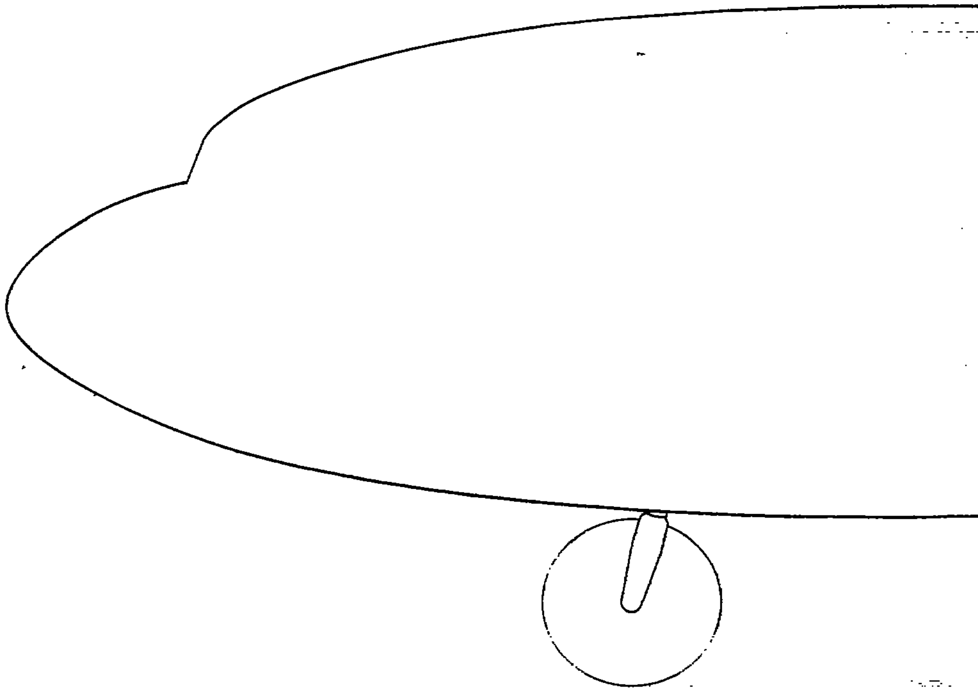
WHEEL EXTENSION (DIAM)	DRAG OF LANDING GEAR AT 100 MPH (LB)
1.06	9.9

FIGURE 13.- UNFAIRED LANDING GEAR, POSITION C.



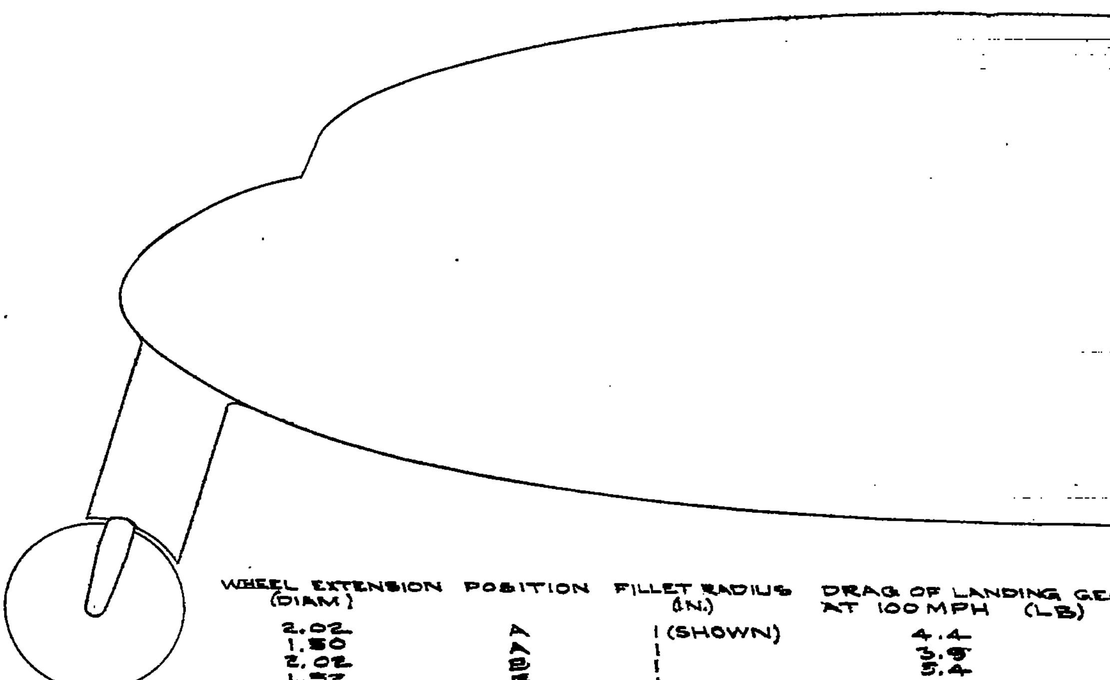
WHEEL EXTENSION (DIAM)	DRAG OF LANDING GEAR AT 100 MPH (LB)
2.00 (SHOWN)	13.0
1.50	8.8

FIGURE 14.- UNFAIRED LANDING GEAR, POSITION D.



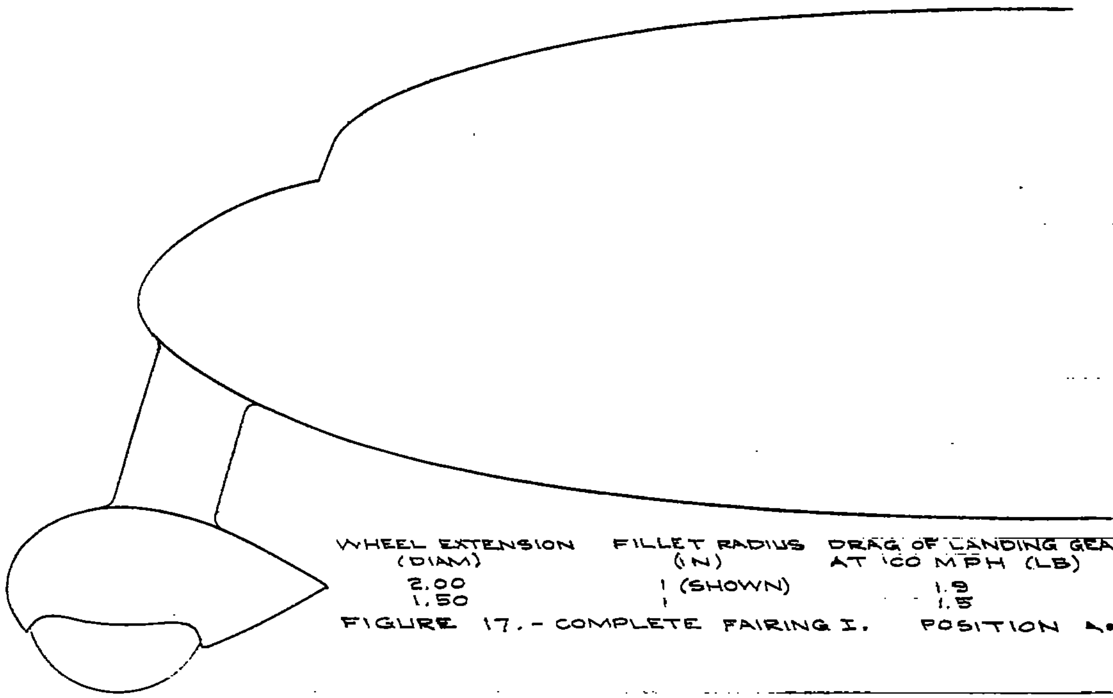
WHEEL EXTENSION (DIAM)	DRAG OF LANDING GEAR AT 100MPH (LB)
1.06	8.0

FIGURE 15.- UNFAIRED LANDING GEAR. POSITION D



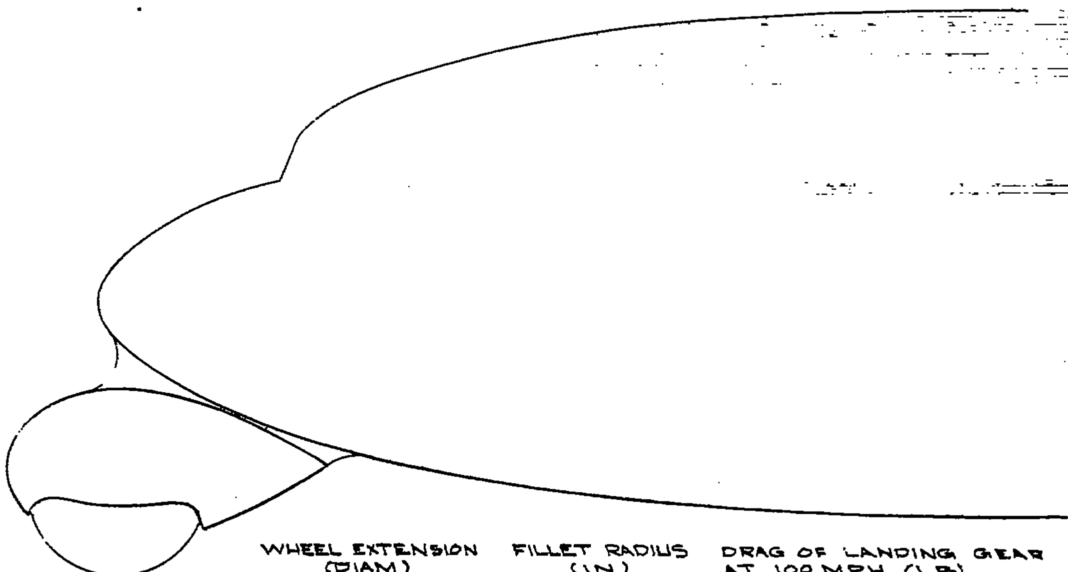
WHEEL EXTENSION (DIAM)	POSITION	FILLET RADIUS (IN.)	DRAG OF LANDING GEAR AT 100 MPH (LB)
2.02	A	1 (SHOWN)	4.4
1.50	A	1	3.9
2.02	B	1	5.4
1.52	B	1	5.2
2.01	C	1	8.3
1.50	C	1	7.5

FIGURE 16.- LANDING GEAR WITH STRUT FAIRING ONLY.



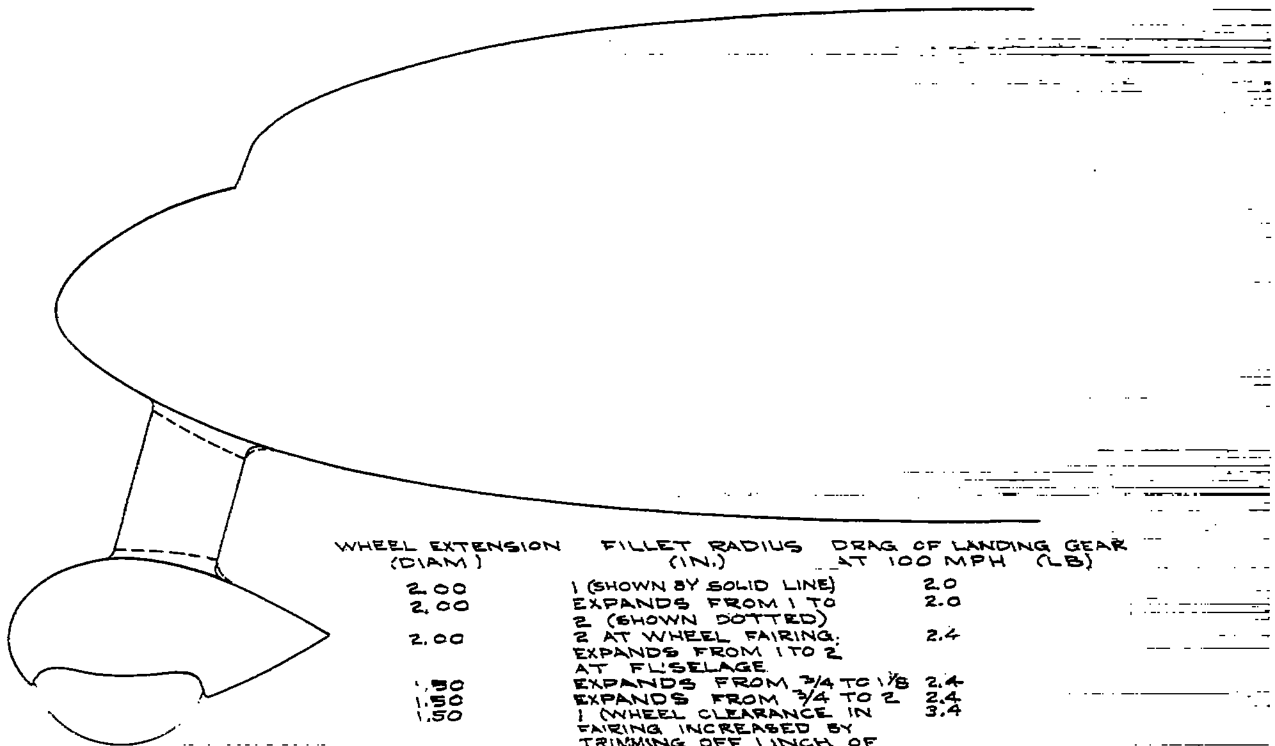
WHEEL EXTENSION (DIAM)	FILLET RADIUS (IN)	DRAG OF LANDING GEAR AT 100 MPH (LB)
2.00	1 (SHOWN)	1.9
1.50	1	1.5

FIGURE 17.- COMPLETE FAIRING I. POSITION A.



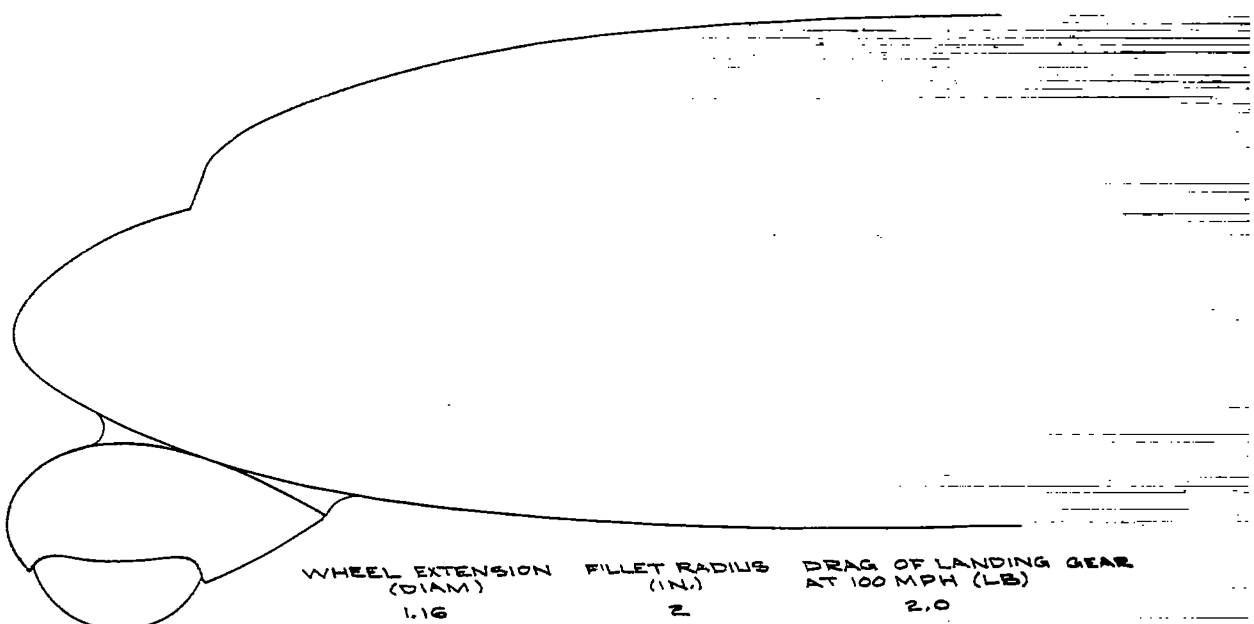
WHEEL EXTENSION (DIAM)	FILLET RADIUS (IN.)	DRAG OF LANDING GEAR AT 100 MPH (LB)
1.25	4 AT LEADING EDGE 2 AT TRAILING EDGE	1.7

FIGURE 18 - COMPLETE FAIRING I. POSITION A.



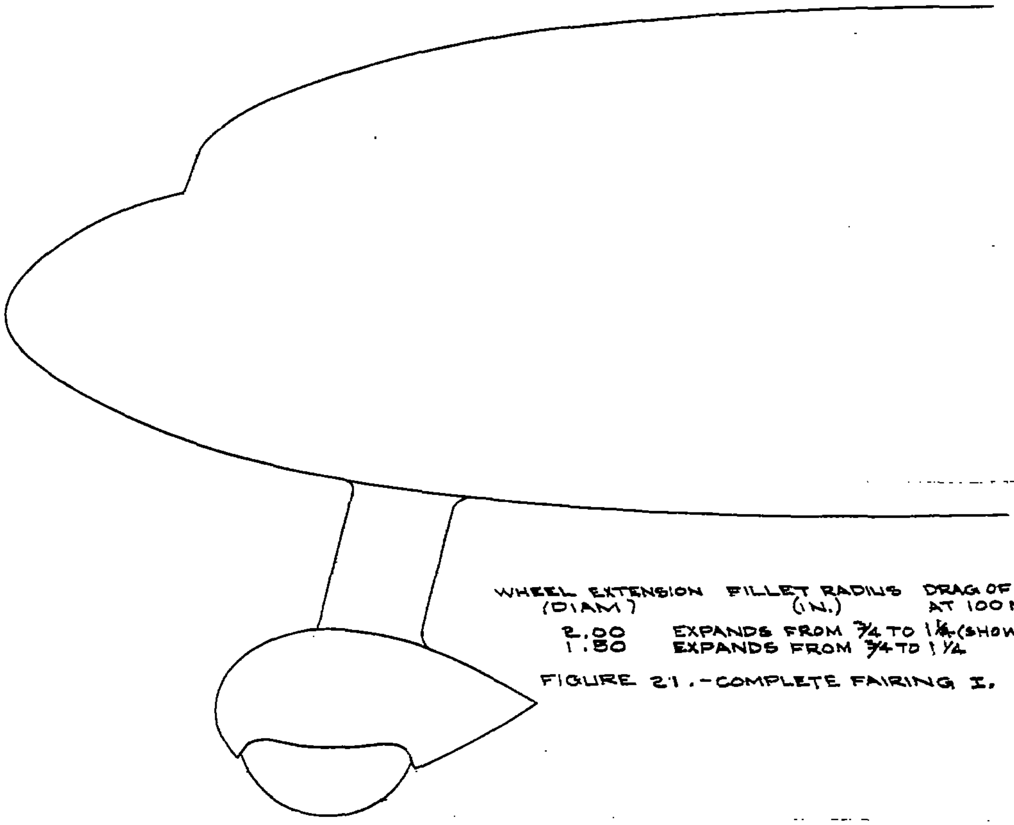
WHEEL EXTENSION (DIAM)	FILLET RADIUS (IN.)	DRAG OF LANDING GEAR AT 100 MPH (LB)
2.00	1 (SHOWN BY SOLID LINE)	2.0
2.00	EXPANDS FROM 1 TO 2 (SHOWN DOTTED)	2.0
2.00	2 AT WHEEL FAIRING; EXPANDS FROM 1 TO 2 AT FUSELAGE	2.4
1.50	EXPANDS FROM 3/4 TO 1 1/8	2.4
1.50	EXPANDS FROM 3/4 TO 2	2.4
1.50	1 (WHEEL CLEARANCE IN FAIRING INCREASED BY TRIMMING OFF 1 INCH OF FAIRING ALL AROUND)	3.4

FIGURE 19.- COMPLETE FAIRING I. POSITION B.



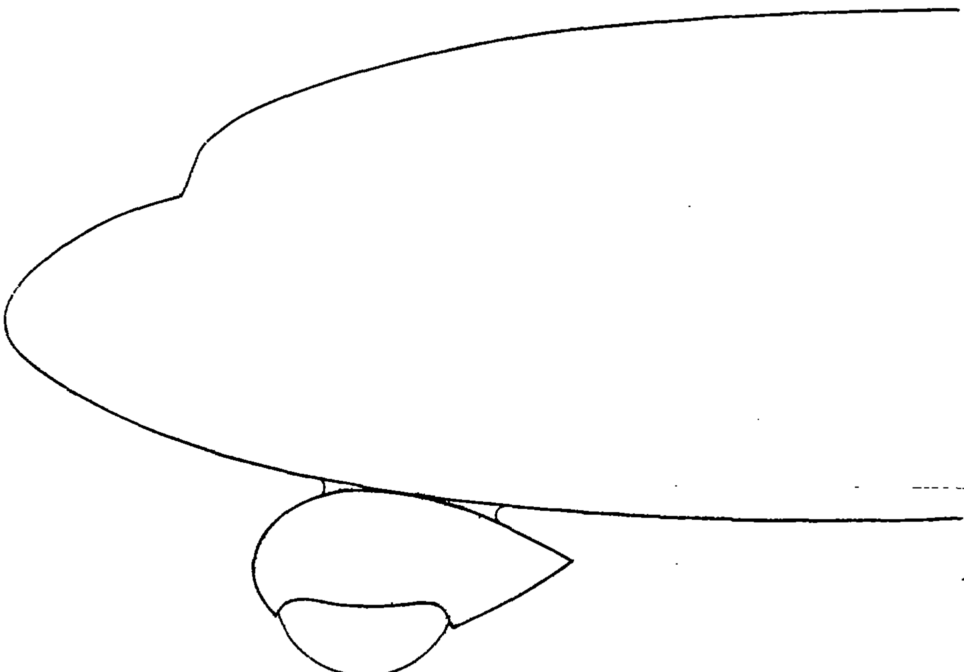
WHEEL EXTENSION (DIAM)	FILLET RADIUS (IN.)	DRAG OF LANDING GEAR AT 100 MPH (LB)
1.16	2	2.0

FIGURE 20.- COMPLETE FAIRING I. POSITION B.



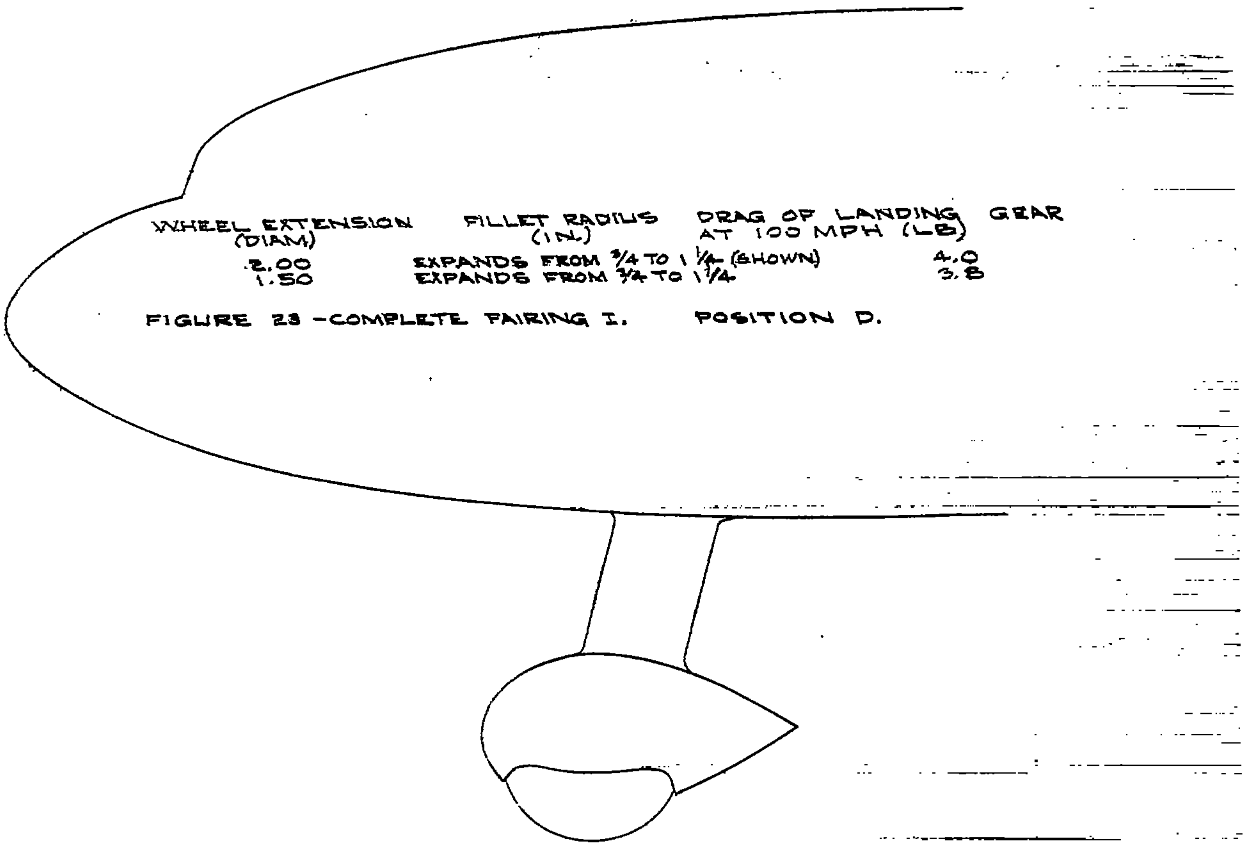
WHEEL EXTENSION (DIAM)	FILLET RADIUS (IN.)	DRAG OF LANDING GEAR AT 100 MPH (LB)
2.00	EXPANDS FROM 3/4 TO 1 1/4 (SHOWN)	2.5
1.50	EXPANDS FROM 3/4 TO 1 1/4	2.5

FIGURE 21.- COMPLETE FAIRING I. POSITION G



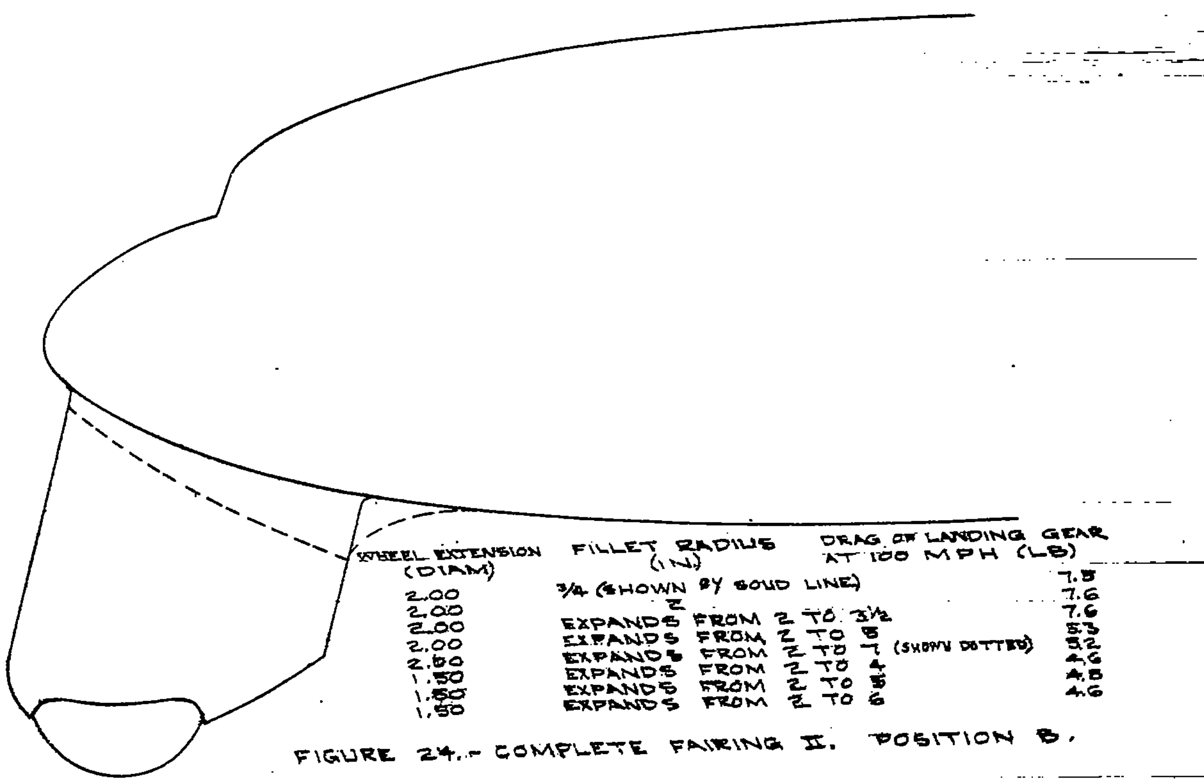
WHEEL EXTENSION (DIAM)	FILLET RADIUS (IN.)	DRAG OF LANDING GEAR AT 100 MPH (LB)
1.11	1	2.6

FIGURE 22. - COMPLETE FAIRING I. POSITION C.



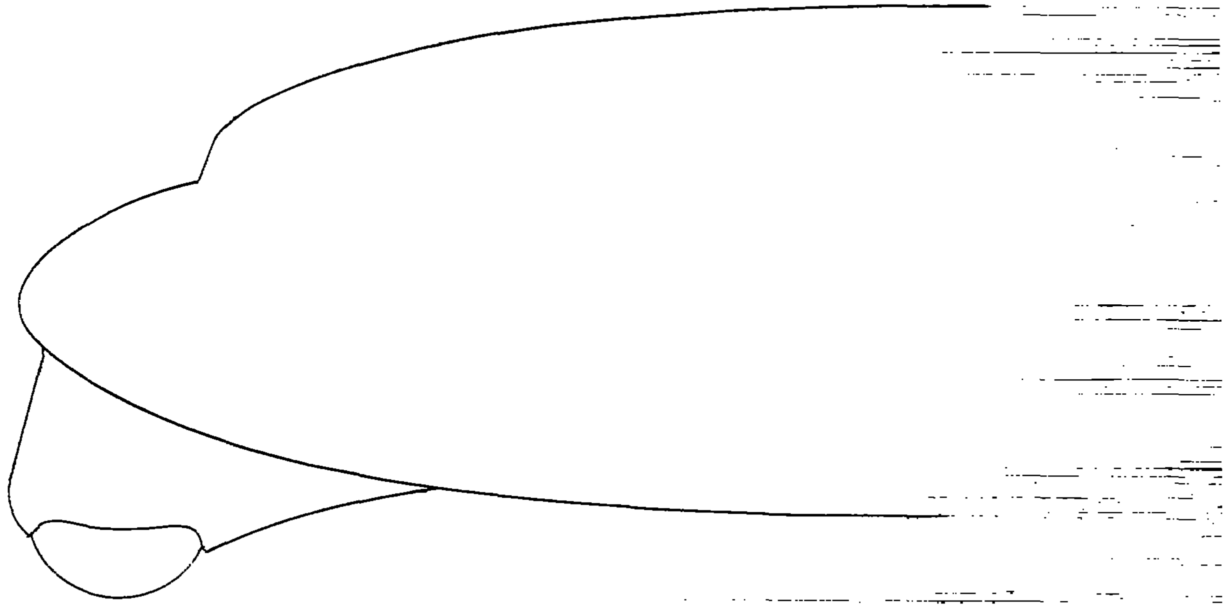
WHEEL EXTENSION (DIAM)	FILLET RADIUS (IN.)	DRAG OF LANDING GEAR AT 100 MPH (LB)
2.00	EXPANDS FROM 3/4 TO 1 1/4 (SHOWN)	4.0
1.50	EXPANDS FROM 3/4 TO 1 1/4	3.8

FIGURE 23 – COMPLETE FAIRING I. POSITION D.



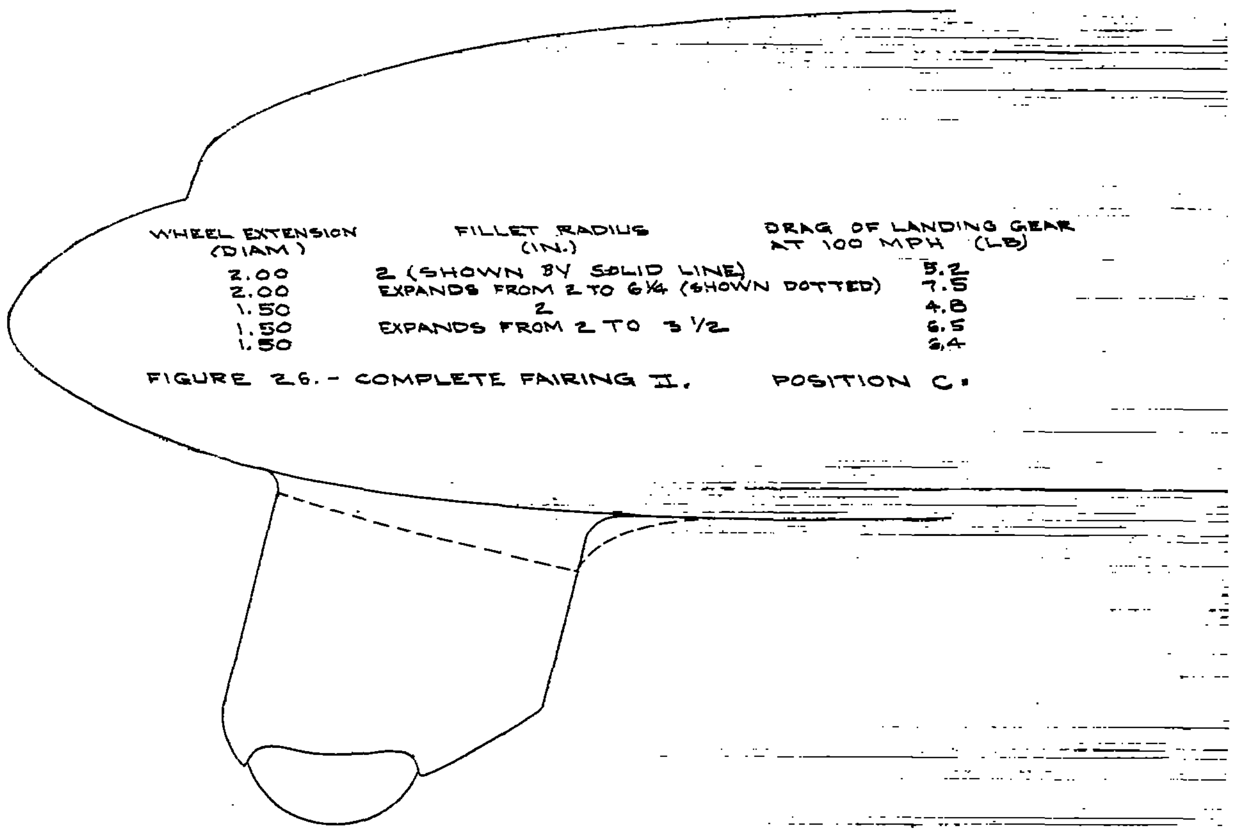
WHEEL EXTENSION (DIAM)	FILLET RADIUS (IN.)	DRAG OF LANDING GEAR AT 100 MPH (LB)
2.00	3/4 (SHOWN BY SOLID LINE)	7.5
2.00	2	7.6
2.00	EXPANDS FROM 2 TO 3½	7.6
2.00	EXPANDS FROM 2 TO 5	5.3
2.00	EXPANDS FROM 2 TO 7 (SHOWN DOTTED)	5.2
1.50	EXPANDS FROM 2 TO 4	4.6
1.50	EXPANDS FROM 2 TO 5	4.5
1.50	EXPANDS FROM 2 TO 6	4.6

FIGURE 24.- COMPLETE FAIRING II. POSITION B.



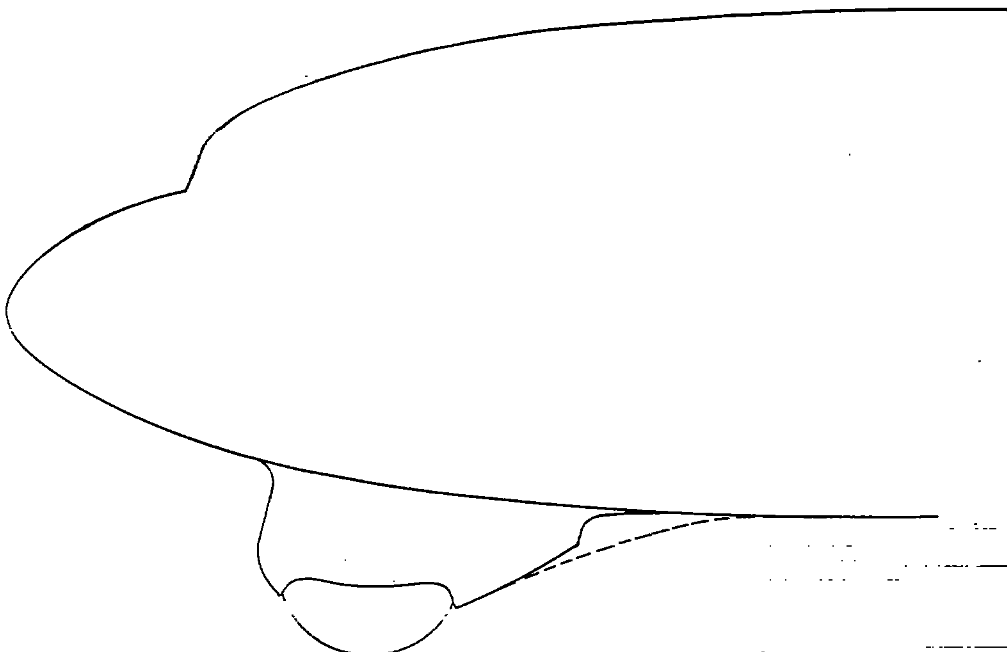
WHEEL EXTENSION (DIAM)	FILLET RADIUS (IN.)	DRAG OF LANDING GEAR AT 100 MPH (LB)
1.06	EXPANDS FROM 2 TO 3	5.9
1.06	EXPANDS FROM 2 TO 4 1/2 (SHOWN)	2.1
1.06	EXPANDS FROM 2 TO 5	2.4

FIGURE 25.- COMPLETE FAIRING II, POSITION B.



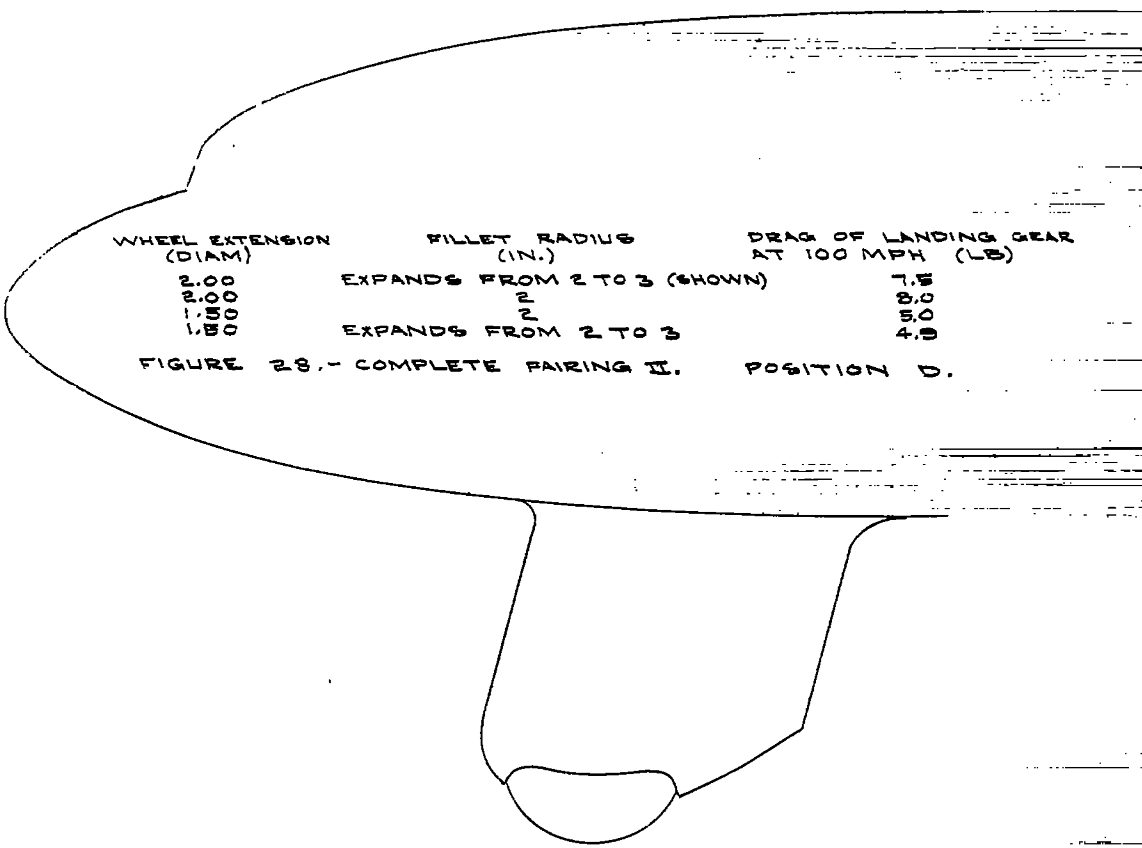
WHEEL EXTENSION (DIAM)	FILLET RADIUS (IN.)	DRAG OF LANDING GEAR AT 100 MPH (LB)
2.00	2 (SHOWN BY SOLID LINE)	5.2
2.00	EXPANDS FROM 2 TO 6 1/4 (SHOWN DOTTED)	7.5
1.50	2	4.8
1.50	EXPANDS FROM 2 TO 3 1/2	6.5
1.50		6.4

FIGURE 26.- COMPLETE FAIRING II, POSITION C.



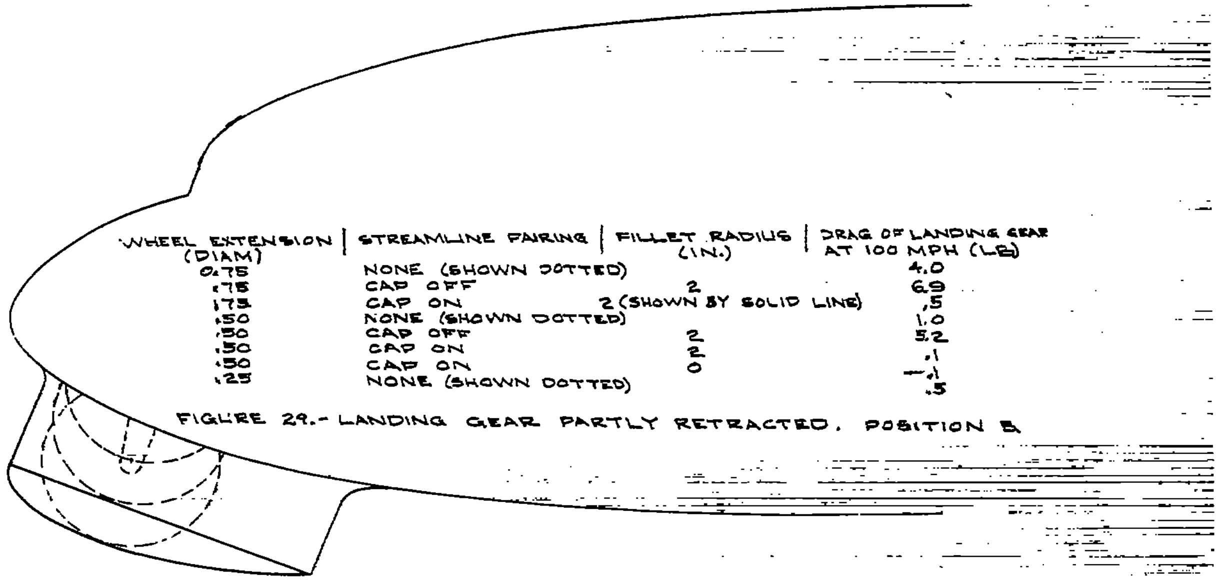
WHEEL EXTENSION (DIAM)	FILLET RADIUS (IN.)	DRAG OF LANDING GEAR AT 100 MPH (LB)
.02	2 (SHOWN BY SOLID LINE)	0.4
1.02	EXPANDS FROM 2 TO 4 1/2	2.7
1.02	EXPANDS FROM 2 TO 8 1/2 (SHOWN DOTTED)	1.5

FIGURE 27.- COMPLETE FAIRING II. POSITION C.



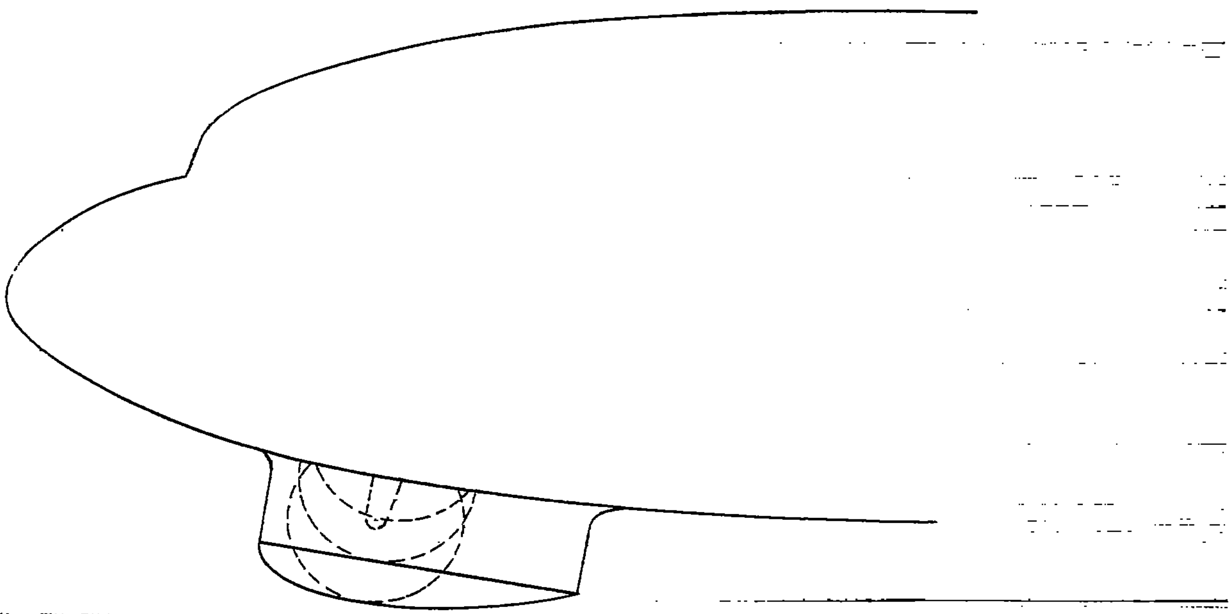
WHEEL EXTENSION (DIAM)	FILLET RADIUS (IN.)	DRAG OF LANDING GEAR AT 100 MPH (LB)
2.00	EXPANDS FROM 2 TO 3 (SHOWN)	7.5
2.00	2	8.0
1.50	2	5.0
1.50	EXPANDS FROM 2 TO 3	4.9

FIGURE 28.- COMPLETE FAIRING II. POSITION D.



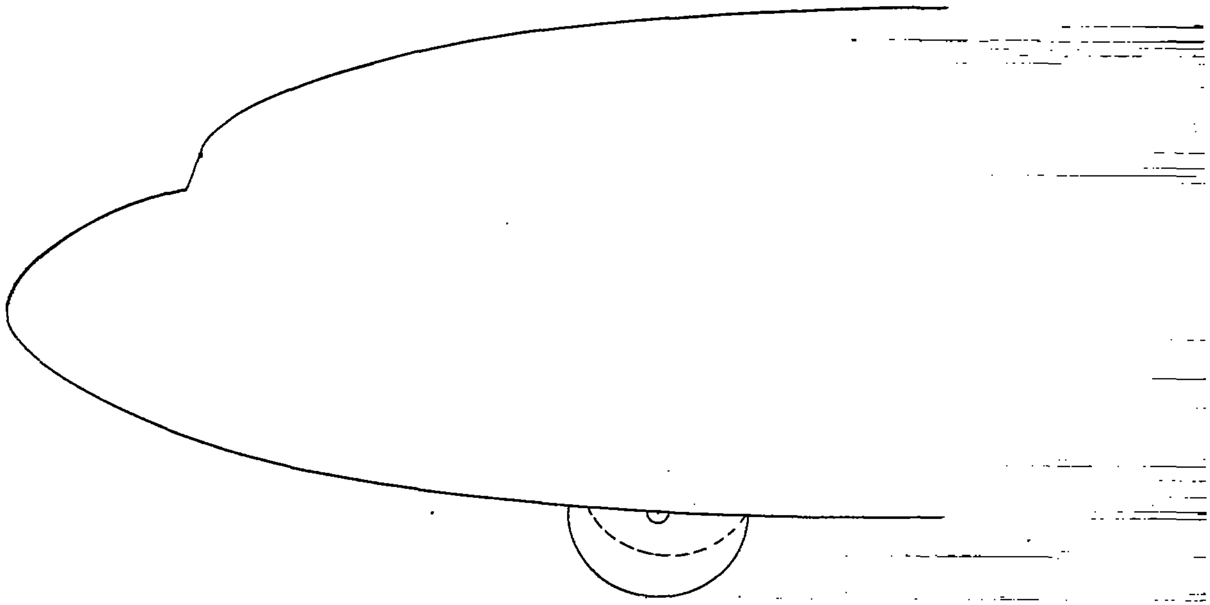
WHEEL EXTENSION (DIAM)	STREAMLINE FAIRING	FILLET RADIUS (IN.)	DRAG OF LANDING GEAR AT 100 MPH (LB)
0.75	NONE (SHOWN DOTTED)		4.0
.75	CAP OFF	2	6.9
.75	CAP ON	2 (SHOWN BY SOLID LINE)	.5
.50	NONE (SHOWN DOTTED)		1.0
.50	CAP OFF	2	5.2
.50	CAP ON	2	.1
.50	CAP ON	0	-.1
.25	NONE (SHOWN DOTTED)		.5

FIGURE 29.- LANDING GEAR PARTLY RETRACTED. POSITION B.



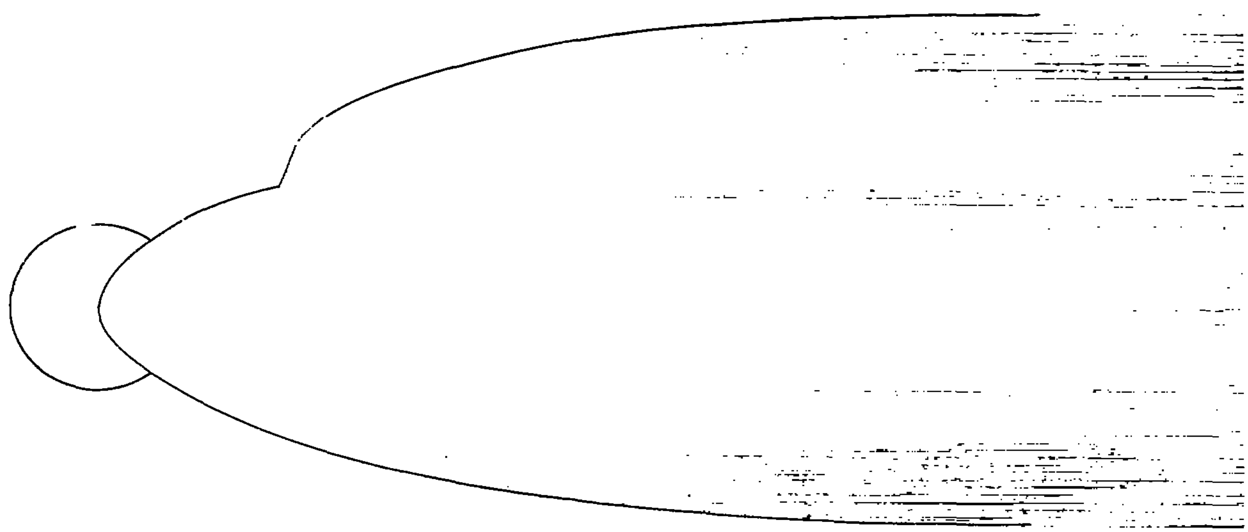
WHEEL EXTENSION (DIAM)	STREAMLINE FAIRING	FILLET RADIUS (IN.)	DRAG OF LANDING GEAR AT 100 MPH (LB)
0.75	NONE (SHOWN DOTTED)		4.8
.75	CAP OFF	2	6.8
.75	CAP ON	2 (SHOWN BY SOLID LINE)	.8
.50	NONE (SHOWN DOTTED)		1.6
.50	CAP OFF	2	4.9
.50	CAP ON	2	.0
.25	NONE (SHOWN DOTTED)		.6

FIGURE 30.- LANDING GEAR PARTLY RETRACTED. POSITION C.



WHEEL EXTENSION (DIAM)	STREAMLINE FAIRING	DRAG OF LANDING GEAR AT 100 MPH (LB)
0.50	NONE (SHOWN BY SOLID LINE)	1.7
.25	NONE (SHOWN DOTTED)	1.2

FIGURE 31.- LANDING GEAR PARTLY RETRACTED, POSITION D.



WHEEL EXTENSION (DIAM)	DRAG OF LANDING GEAR AT 100 MPH (LB)
0.50	0.6

FIGURE 32.- UNFAIRED WHEEL PARTLY RETRACTED INTO TIP OF NOSE.

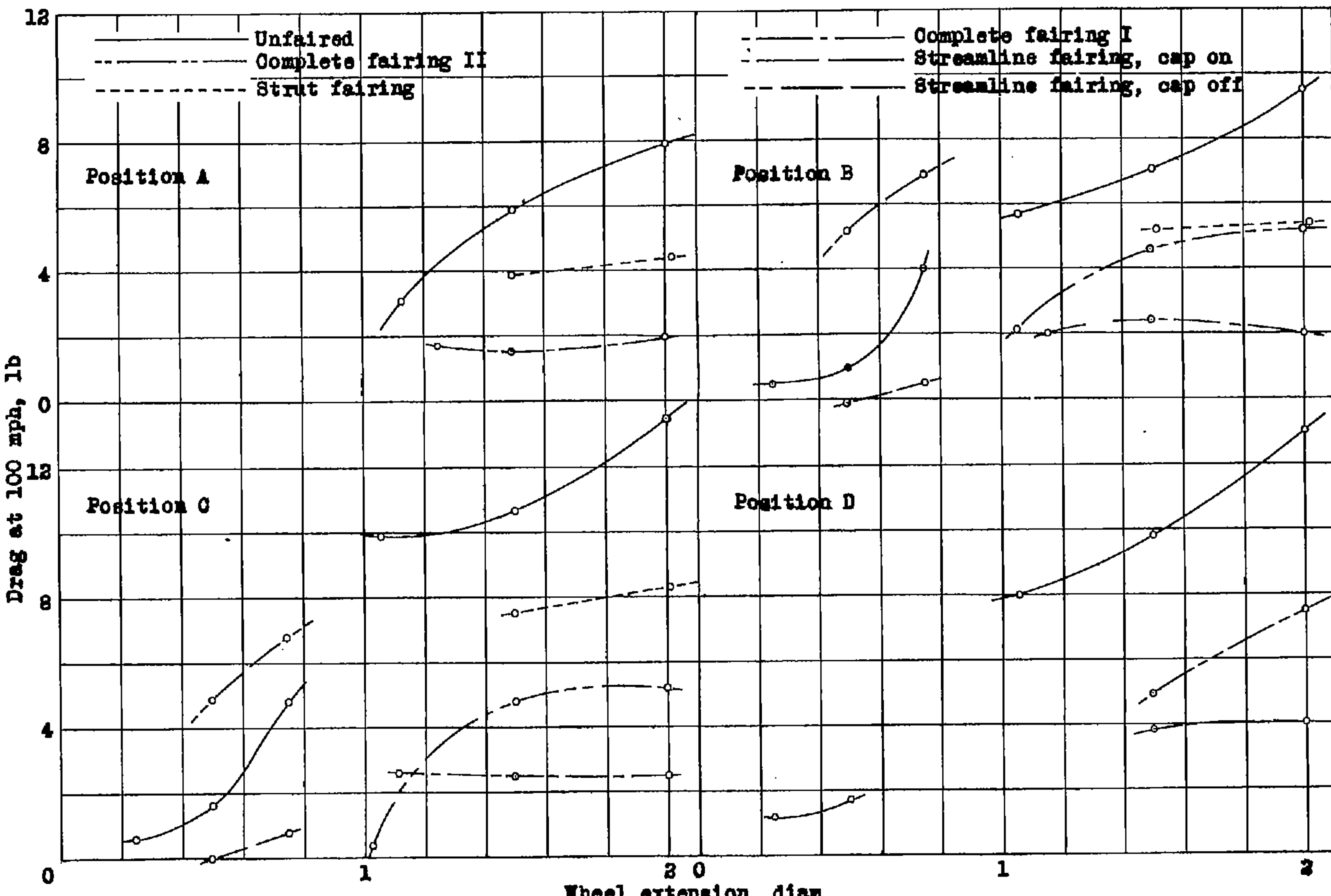


Figure 33.- Relation of wheel extension to drag of landing gear. The wheel opening is open for all partly retracted conditions (all extensions less than 1 diameter) but is closed for all of the others.

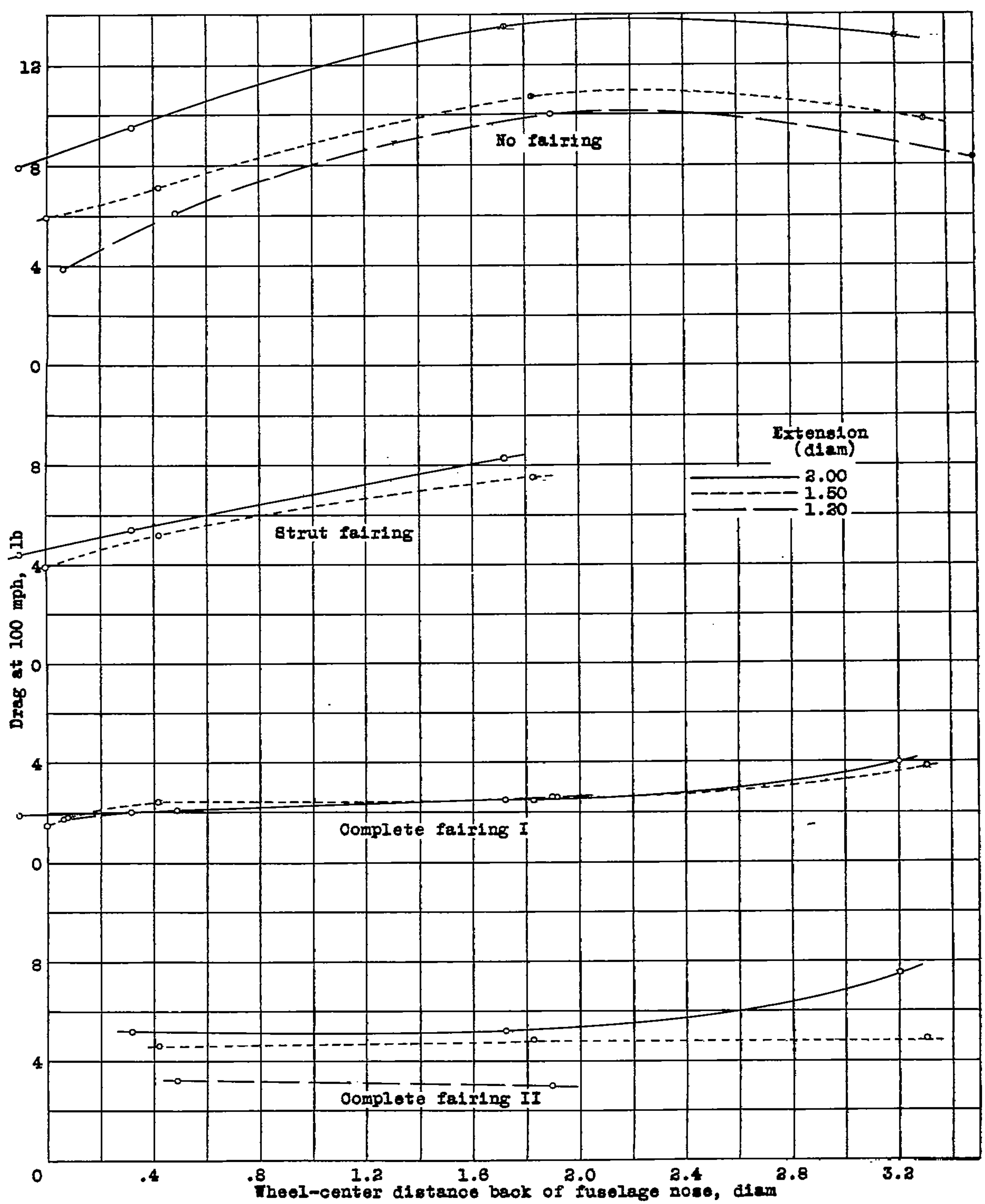


Figure 34.- Relation of drag of nonretracted landing gear to distance back of nose.

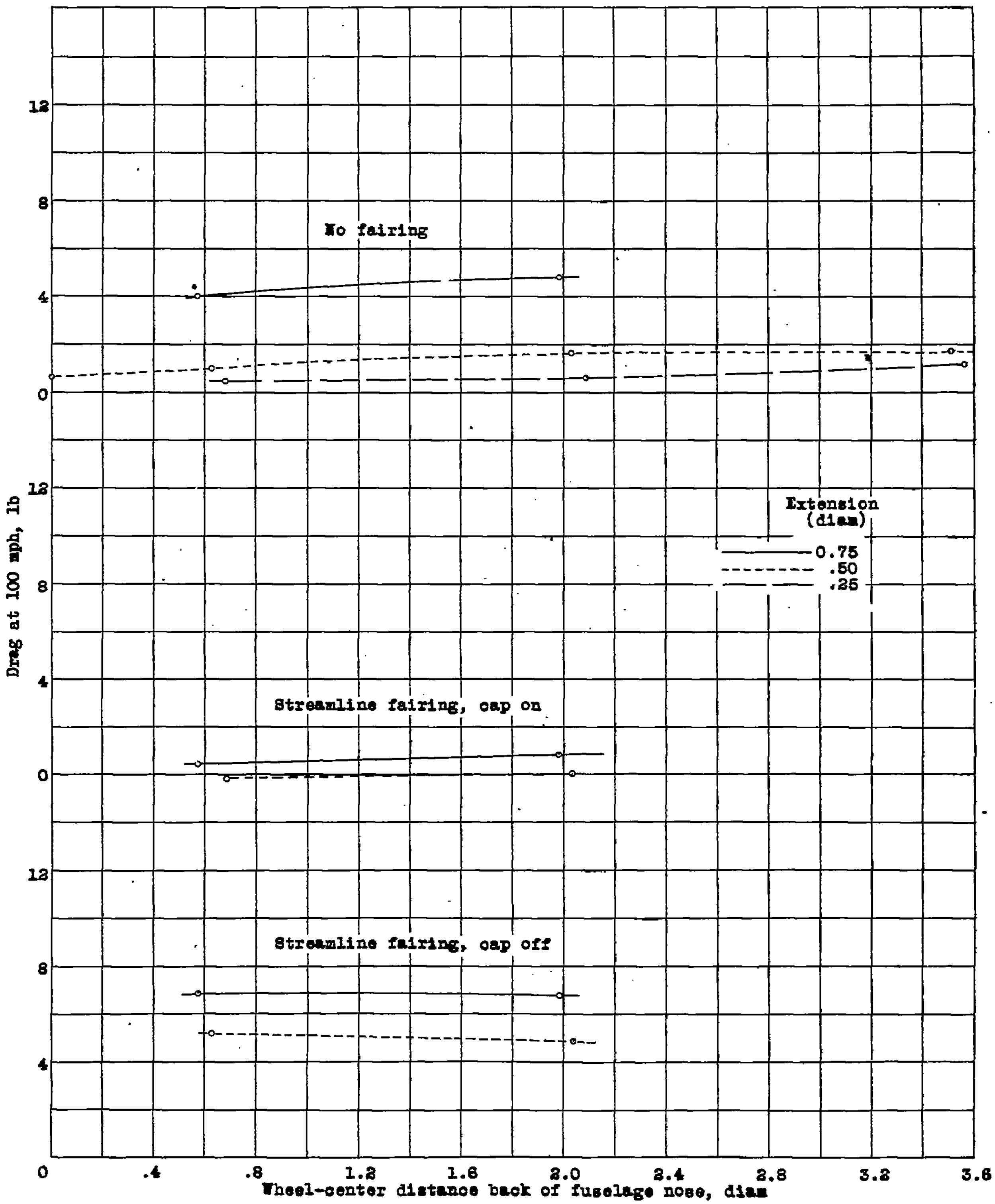


Figure 35.- Relation of drag of partly retracted landing gear to distance back of nose.